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Barriers to and drivers for UK bioenergy development

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ABSTRACT

Barriers to UK bioenergy development arise from a number of technical, financial, social and other constraints. Likewise, the drivers for using bioenergy are numerous and diverse. A range of these barriers and drivers have been identified through a comprehensive literature and case study review, and then assessed through an online questionnaire, completed by stakeholders from across the UK bioenergy industry: farmers/suppliers, developers/owners of bioenergy projects, primary end-users, and government/policy stakeholders. The results are presented in the form of 'spider web' diagrams. The most critical barriers and drivers relate to economic factors of bioenergy projects. Farmers/suppliers and developers are influenced by production costs and benefits, whilst primary end-users of bioenergy are concerned mainly with the cost of purchasing energy resources. Common drivers for all stakeholders were found to be reducing carbon emissions and the dependency on fossil fuels. In order to satisfy the needs of stakeholders schemes must be both economically attractive and environmentally sustainable for projects to be successful.

Contents

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1. Introduction

In response to the concerns over climate change and energy security, the UK Government recently set out plans to reduce greenhouse gas emissions by 80% over 1990 levels by 2050, with identifiable progress being made by 2020 [1]. In addition, the UK has agreed to a EU target to produce 15% of the UK's energy from renewable sources by 2020 [2]. It has been suggested that biomass will form a significant part of this [3,4]. Biomass to bioenergy is an attractive solution in reducing carbon emissions as it can be used for the production of heat, and electricity, or as a liquid transport fuel. The UK Biomass Strategy proposes to increase the use of biomass for heat, electricity and biofuels, and outlines the potential UK supply of feedstocks up to 2020 [5]. However, it is clear that the UK bioenergy industry will need to expand significantly over the next decade if EU and UK Government targets are to be met [3,4].

Current patterns of bioenergy utilisation vary between the UK and some of its neighbours. In many European countries, such as Austria, Finland, Germany and Sweden, bioenergy makes a significant contribution towards total energy generation (see, for example [6,7]). There a range of financial measures and supportive policies have helped promote the use of bioenergy [8–10]. For example, renewable electricity in Germany is rewarded through a feed-in-tariff mechanism, which provides a guaranteed income [11]. In comparison to other countries, the UK is some way from reaching its bioenergy capacity [7,12]. The challenge facing both the UK and the other EU states is to accelerate the implementation of bioenergy systems to meet EU targets for renewable energy use and reducing carbon emissions [13], whilst ensuring a sustainable feedstock supply.

In the present study a number of barriers have been identified through an assessment of different bioenergy project case studies. Various incentives, or 'drivers', for bioenergy development have also been assessed. Several cases from across the UK were analysed to identify what prevents the successful implementation of a bioenergy scheme, and what the motivations are behind different schemes. In order to confirm these barriers and drivers, an online questionnaire was developed for each of the four main stakeholder groups: farmers/suppliers, developers, end-users and government/policy makers/advisors. Respondents were asked to assess each barrier and driver, rate them in importance, and to provide any additional comments.

2. UK bioenergy policy

Government-set regulations put in place in recent years have created an interest in producing energy from biomass. Electricity generation from renewable sources, for example, has been incentivised via the introduction of the Renewables Obligation, which obliges UK electricity suppliers to source a fixed percentage of their electricity from renewable sources [14]. Clean energy cash-back schemes (feed-in tariffs) were introduced in 2010, where householders and organisations are paid a fixed rate if they use biomass and other low carbon sources to generate electricity [13].

Other British Government initiatives include the deployment of the Renewable Transport Fuel Obligation [15], which requires an increasing level of sustainable biofuels for road transport. There are currently no policy drivers for renewable heat energy in the UK. However, energy for space heating accounts for nearly half of all the UK's carbon emissions [16] and the UK Government has considered policy options for heat following their 'Heat Call for Evidence' [17]. A renewable heat incentive is currently under consultation and may be introduced by 2011 [4].

A number of subsidies are available within the UK to help grow feedstocks for bioenergy processes, including the 'Single Payment', the 'Entry Level Environmental Stewardship Scheme', and the 'Energy Aid Payment Scheme' [3]. Additionally, the 'Energy Crops Scheme' helps finance the establishment of Miscanthus and Short Rotation Coppice [18]. Another market 'push' incentive, the 'Bioenergy Infrastructure Scheme', helps to develop biomass supply chains from harvest through to delivery of heat and power to end-users. It provides grants for essential, dedicated equipment, such as chippers [19]. Market 'pull' incentives have been provided by the 'Bio-energy Capital Grants Scheme' [20]. Other schemes that support the biomass supply chain include the 'Biomass Heat Accelerator project' [21] and the 'Low Carbon Buildings Programme' [22]. The Forestry Commission also run various biomass programmes, including the Biomass Energy Centre [23].

In July 2009 the UK Government set up the 'Office for Renewable Energy Deployment' (ORED) to co-ordinate actions aimed at achieving the 2020 renewable energy targets [4]. ORED will help stimulate investment and develop supply chains in all renewable energy technologies, but does have a specific objective to encourage and enable more use of 'sustainable bioenergy' [4].

3. Bioenergy in the UK

In 2008 biomass electricity generation accounted for 2.4% of the UK's electricity generation, heat from biomass generated less than 1% of heat demand, and biofuels accounted for less than 1% of the UK's road transport fuel [24]. The UK Government's Renewable Energy Strategy consultation suggests that in order to achieve up to 14% renewable heat and 37% renewable electricity, around 80 TW h of bioenergy would be required [3]. This represents a more than 10-fold increase in production over the next decade. Resource assessments suggest that there is between 64 and 78 TW h of domestic biomass resource currently available for bioenergy production for heat and electricity [3].

Inhibitors to UK bioenergy development can be observed via a number of Government-funded biomass energy projects that, for various reasons, have experienced difficulties in implementation. In 2004, Government funds of £18m were awarded to five bioenergy plants across the UK, to date none of these projects are fully operational [25]. Several studies have indicated a pattern of barriers that impede the development of bioenergy (for example [26–29]). In the UK the main barriers to bioenergy projects include (listed alphabetically):

- financial problems during operation and lifespan of plant [30];
- increased transport around bioenergy plants [28];
- local planning approval [4];
- location of bioenergy plant–visual impacts [27];
- mistrust between local community, developers and agencies; and the credibility of developer [27,31];
- other environmental impacts, for example odours, noise, etc. [10];
- technical problems associated with conversion techniques [30].

Barriers to the development of bioenergy differ at varying stages of project implementation. Such stages include technical

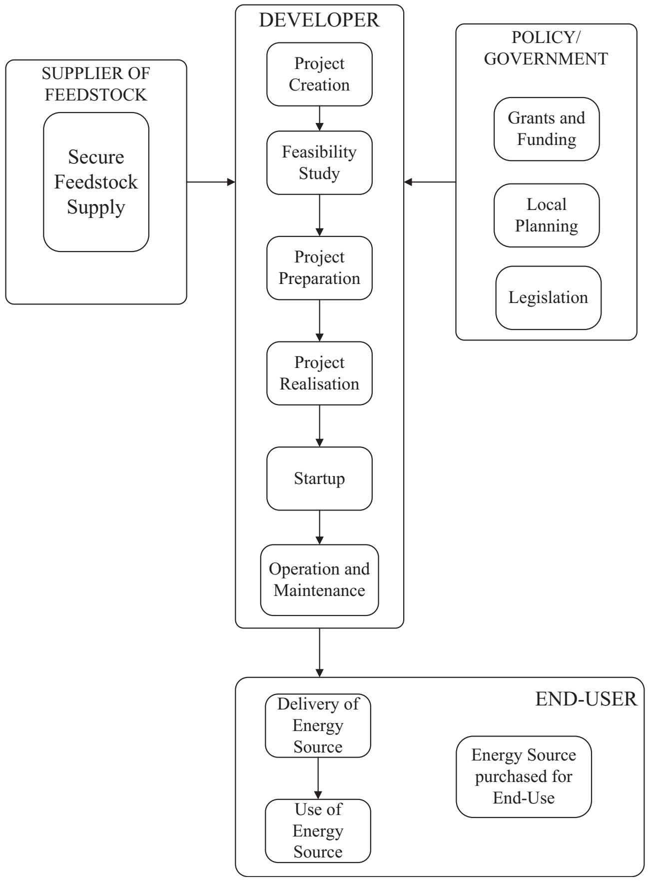


Fig. 1. Linkage between stakeholder groups associated with bioenergy projects—concept from Ecofys [33] and Deublein and Steinhauser [34].

and project development; project modification; design approval and construction monitoring; performance testing and handover; and finally, operation and maintenance [32]. Fig. 1 shows the supply chain and external influences on a typical bioenergy project (adapted from Ecofys [33] and Deublein and Steinhauser [34]). This diagram incorporates the sequence of project stages that a developer needs to undertake.

4. Bioenergy pathways and project implementation

The reasons for unsuccessful bioenergy projects can originate from any, or multiple, stages of the project's development chain. The supply chain (see Fig. 1), considered a critical component for the success of bioenergy development [4,35], is ultimately created between the demand for bioenergy and the supply of the energy resource. The four main stakeholders that can affect a bioenergy supply chain are: feedstock supplier, plant developer/owners, government department policy advisors and primary end-users. Suppliers are involved in the production and supply of biomass feedstock, developers are concerned with operability and implementation of bioenergy conversion plants, whilst primary end-users purchase the primary biomass energy. Government/policy stakeholders are involved in guiding bioenergy development in the UK through the introduction of economic instruments and other incentives.

There are a large number of bioenergy 'pathways' or process routes, for example, Hammond et al. [36,37], and barriers and drivers for each of these could potentially be different. Thus, the barriers to producing biodiesel from palm oil in (say) South East Asia will be different to those for the production of heat from farm waste in the UK. However, in the present study these different pathways have not been specifically distinguished as the research was aimed at indentifying the more general barriers and drivers to bioenergy. This is in accordance with previous UK governmental bioenergy studies and strategies for bioenergy production (see, for example [4,5,35]).

5. Methodology for identifying barriers and drivers to UK bioenergy development

5.1. Online survey

Barriers and drivers were identified from existing literature, and from the analysis of case studies from UK bioenergy projects. An online survey was then carried out for each of the four stakeholder groups in a similar manner to the risk assessment of the UK electricity sector by Hammond and Waldron [38]. The online questionnaire postulated a list of possible barriers and drivers to the development, use and support of bioenergy. Respondents were asked to assess the importance of each of the barriers and drivers on a 4-point scale [critical importance to unimportant]. They could indicate if they were 'undecided', and also had the opportunity to add other barriers or drivers. The study focused on more overarching aspects of development as opposed to specific (or plant-dependent) issues. Responding stakeholders in each group were identified through the literature, and from attending a number of UK bioenergy-related events during 2007–2008. Respondent suitability was assessed based on previous experience or a relevant interest in the bioenergy field.

Having proposed the main barriers and drivers for each stakeholder category, four online questionnaires were constructed (one for each group). Respondents were asked to rate how important each barrier and driver was for the development of bioenergy. The questionnaires offered the respondents five choices: 'critical' importance, 'very' important, 'moderate' importance, 'unimportant' or 'undecided'. The respondents were contacted via emails with a covering document explaining the details of the research. The email incorporated a web link directing them to the online survey. Once the questionnaire was completed, the respondents submitted their assessments, these were stored in an online database. Data were collated into the four stakeholder categories, and analysed to determine the most important barriers and drivers to UK bioenergy development.

5.2. Barriers and drivers for biomass feedstock suppliers

The barriers and drivers that were specified in the questionnaire for feedstock suppliers are reproduced in Table 1. There could be a perceived difficulty of growing novel energy crops in comparison to other food crops [39], although farmers may be willing to invest in energy crops to diversify the market. Low or uncertain returns on investment could also be seen as an important barrier to the development of bioenergy feedstock [40]. Uncertainties over grant or funding support are a potential barrier to the take-up of biomass feedstock. It has been suggested that without financial support the uptake of bioenergy crop production would be considerably lower [40]. Environmental impacts, such as loss of biodiversity effects, may be viewed by farmers as a barrier towards feedstock development.

5.3. Barriers and drivers for biomass process plant developers/owners

Barriers to the development or ownership of a bioenergy project (see Table 2) include the adoption of a conversion technology that could either be financially or practically unproven. This barrier is considered applicable to many bioenergy pathways. Other barriers

Table 1
Barriers and drivers to the development of bioenergy for feedstock suppliers.

Barriers	Drivers
Feedstock supplier	
Competition vs. other investments	Attractiveness of a growing bioenergy market
Lack of feedstock experience	Availability of financial support
Limited/uncertain return on investment	Good technique for waste utilisation
Negative environmental impacts of feedstock	Market diversification
Perceptual challenges of feedstock	Meeting governmental energy/carbon/waste targets
Physical resource limitations (land availability)	Other environmental benefits (other than CO_2 reduction)
Resource intensive feedstock	Possible reduction in carbon emissions
Uncertainties of financial support	Profitable return on investment
Unclear legislative limitations	Reduction in fossil-based fuels
Unsettled bioenergy market (unreliable buyer)	

Table 2
Barriers and drivers to the development of bioenergy for process plant developers/owners.

Barriers	Drivers
Plant developer/owner	
Competition vs. other renewable energy options	Availability of financial reward/support mechanisms
Lack of feedstock supply (resource availability)	Bioenergy supply consistency vs. other intermittent energy options
Low primary-end-user demand	Bioenergy use versatility
Perceptual challenges of bioenergy plant	Increased bioenergy interest from end-user
Planning and installation Issues	Market diversification/opportunity
Possible negative environmental impacts	Possible reduction in carbon emissions
Uncertain development and operational costs	Reduction in fossil-based fuels
Uncertainty of conversion technology/equipment	Variety of feedstock use for bioenergy (resource diversification)
Unclear and complex legislative issues	

include a lack of local feedstock supply, thereby forcing developers to import from outside the UK. The import of wood-pellets into the UK signifies the lack of feedstock supply within the country [41]. Financial considerations clearly give rise to a number of potential drivers and barriers to the development of bioenergy projects. Proposed drivers for bioenergy include Governmental support mechanisms (economic instruments and other incentives). However, uncertainties about the financial costs associated with operation, and maintenance of bioenergy plants, as well as the cost of end-product distribution were all anticipated to be significant barriers [30].

5.4. Barriers and drivers for primary end-users of bioenergy

Primary end-users of bioenergy range from electricity suppliers (seeking to utilise ROCs) to domestic heating users (wanting to reduce dependency of fossil-based fuels and, arguably, wishing to improve environmental impacts associated with energy use). The associated barriers (see Table 3) include financial implications of bioenergy. High buying costs of biomass resources, with respect to other sources of fossil-fuel derived energy (or even other renewable energy options), discourage the use of bioenergy. Similarly, uncertainties within the bioenergy market, such as seasonal variability of feedstock supply, will ultimately create volatile buying costs for various types of bioenergy.

5.5. Barriers and drivers for government/policy

Table 4 shows the barriers and drivers related to government/policy stakeholders. These are linked to how these ‘actors’ would support or discourage the use and development of bioenergy.

Barriers specified in the questionnaire for this stakeholder group include the competition that bioenergy could face against other renewable energy options, such as wind energy or solar. Another barrier is the postulated link between bioenergy crop growth and the rise in food crop prices [42,43]. Obtaining feedstock from ‘unsustainable’ sources will also have negative implications on the perceived environmental benefits of using bioenergy. This could ultimately hinder the attainment of government-set targets of carbon reductions, and the objective of improving fuel security [16]. Financial support mechanisms, however, may result in the adoption of unproven conversion technologies. They might then ultimately not yield a suitable return on investment.

A variety of Governmental strategies seek to encourage the development of bioenergy [4,5,44]. These are aimed at: increasing energy security, reducing carbon emissions, and reducing overall

Table 3
Barriers and drivers to the development of bioenergy for primary end-users of bioenergy.

Barriers	Drivers
Primary end-user	
Bioenergy costs vs. fossil-fuel	Ability to penetrate most energy markets (versatile)
Infrastructure and other costs	Bioenergy use consistency vs. other intermittent energy options
Legislative issues	Direct substitute of fossil-based fuels
Low supply of bioenergy	Good technique for waste utilisation
Perceptual challenges of bioenergy use	Help in supporting governmental schemes
Preferential over other renewable energy options	Investment opportunity into renewable energy
Seasonal effects of bioenergy supply	Positive effects on image
Uncertainty of adaptability	Possible reduction in carbon emissions
Unsettled/changing bioenergy market	Reduction in fossil-based fuels

Table 4
Barriers and drivers to the development of bioenergy for government/policy stakeholders.

Barriers	Drivers
Government/policy	
Competition vs. other renewable energy options	Bioenergy supply consistency vs. other intermittent energy options
Lack of feedstock supply (resource availability)	Bioenergy use versatility
Legislative issues regarding bioenergy	Decentralisation of energy capability
Negative effects on food crop prices	Good technique for waste utilisation
Negative global environmental impacts	Increase rural development and economy
Negative local environmental impacts	Increased fuel security
Perceptual challenges	Possible reduction in carbon emissions
Uncertainty of conversion technology/equipment	Reduction in fossil-based fuels
	Variety of feedstock use for bioenergy (resource diversification)

dependency on fossil fuels. Incentives for the development of bioenergy (such as economic instruments of various types) are seen as important factors from a government/policy perspective. Parallel to these drivers are incentives for diversifying the use of waste. Reducing waste to landfill through the Landfill Directive, for example, encourages the use of biomass waste for energy purposes [5].

6. Interpretation of findings

6.1. Online survey outturn

A summary of the key findings from the online stakeholder survey is outlined below, along with an interpretation and implications of the results. The results are presented in the form

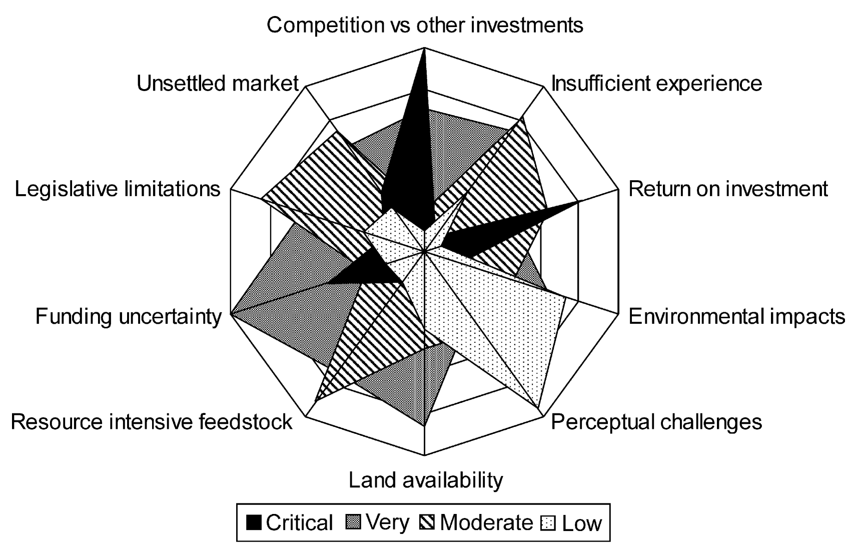


Fig. 2. Barriers to bioenergy development according to farmers/suppliers of biomass feedstock.

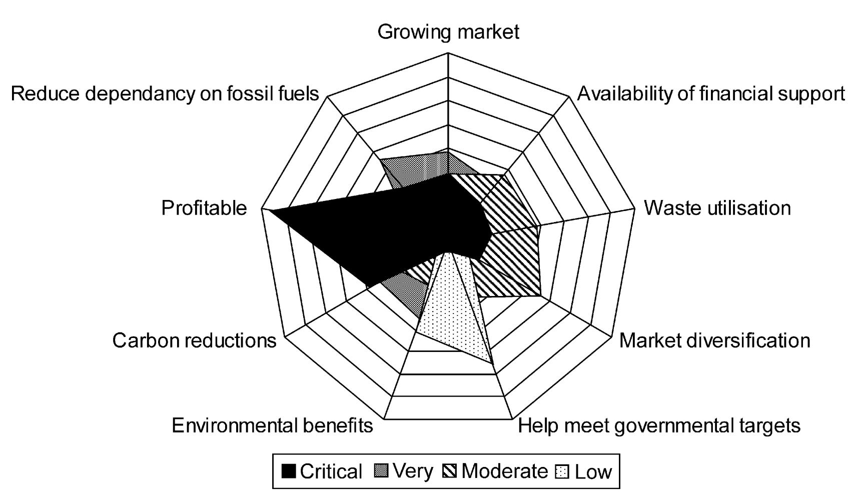


Fig. 3. Drivers to bioenergy development according to farmers/suppliers of biomass feedstock.

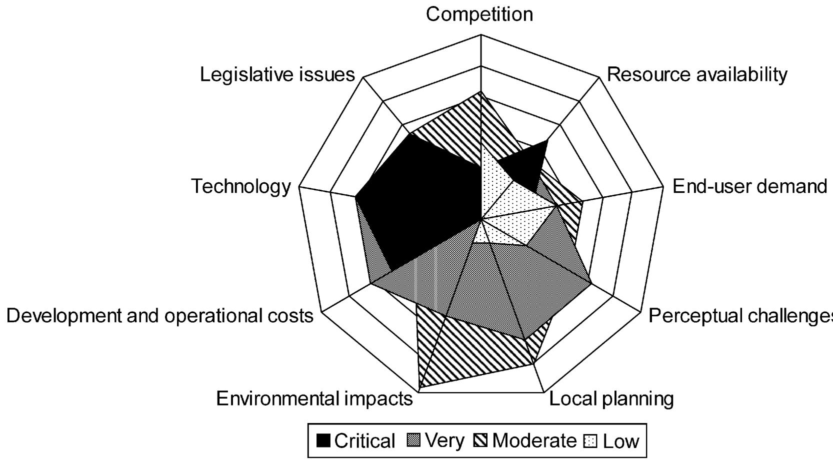


Fig. 4. Barriers to bioenergy development according to developers/owners of bioenergy projects.

of 'spider web' diagrams in Figs. 2–9. The response rate of the questionnaire was just over 45%, with a total of 72 responses from across the UK bioenergy industry. This is a relatively good outcome in comparison, for example, with the online risk survey of the UK electricity sector by Hammond and Waldron [38]. There the response rate was one third of those originally asked to complete the questionnaire.

6.2. Farmers and biomass feedstock suppliers

6.2.1. Barriers to an increase in UK biomass supply

The results show that almost all (85%) of farmers and suppliers see competition from other investments as a 'critical' or 'very important' barrier to increasing the supply of biomass feedstock (see Fig. 2). The primary reason given was that, at present, annual food crops remain more economical than perennial energy crops. This finding is consistent with a recent study on the domestic supply of perennial energy crops by Sherrington et al. [40], who found that there was uncertainty about the financial viability of energy crops in the short term. In addition, there were uncertainties surrounding the production costs, potential yields, and market prices. Energy crop prices were viewed as being low compared to wheat (see also [40]). There are also risks associated with being tied into long-term contracts, as this is not the traditional mechanism for farming. Uncertainty over grant funding was identified as the second most important barrier. Few farmers would consider growing energy crops without a grant regime, due to high up-front capital costs and the uncertainty over net income.

Financial return on investment was the third most important barrier identified by respondents in this group, due to the potential impacts on a farm's business structure. Profit margins for biomass feedstock in the UK can be low or even negative, resulting in a requirement for Government support mechanisms (see Section 2). Land availability was identified as the next most important barrier, with farmers likely to grow energy crops on their least productive land (according to Sherrington et al. [40]). In the short term, first generation crops, such as oilseed rape and wheat, require large areas to produce sufficient amounts of bioenergy to meet UK targets. For example, it is estimated that between 1.2 Mha and 1.5 Mha of UK land will be needed to meet the original 5% RTFO target [5,36]. This highlights the heavy reliance on land-use to produce first generation energy crops. Alternative biomass sources, such as waste, therefore need to form an integral part of the future development of UK bioenergy (see Hammond et al. [37]). This will help to reduce the need for direct and indirect land-use change, as well as alleviating the fuel vs. food issue. However, It is difficult to collect large quantities of biomass wastes, due to its dispersed nature.

6.2.2. Drivers for an increase in UK biomass supply

The ability to 'make a profit' was by far the most important driver for farmers, and biomass feedstock suppliers (see Fig. 3),

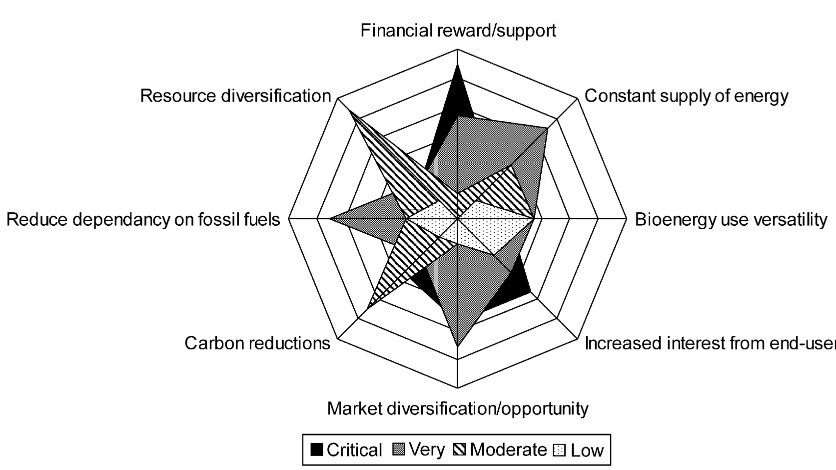


Fig. 5. Drivers to bioenergy development according to developers/owners of bioenergy projects.

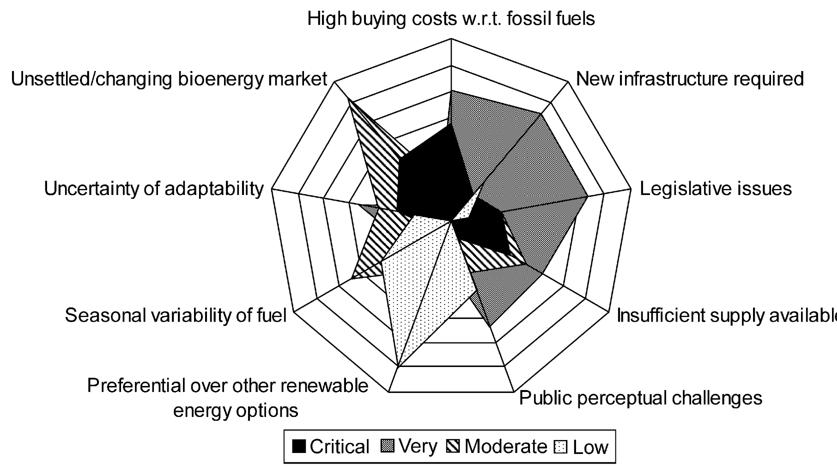


Fig. 6. Barriers to bioenergy development according to primary end-users of bioenergy.

with 90% of respondents stating this was either 'critical' or 'very important' to the development of energy crop production in the UK. This underpins the necessity of energy crops and other biomass feedstock being economically viable. Perennial energy crops are a significant change from the more traditional annual farming cycle, as they make it much harder to adjust production to the requirements of market conditions and prices. This perhaps explains the present low uptake of crops under the Energy Crops Scheme [4]. If such crops can become economical in the long term, then their introduction offers a lifestyle choice for farmers. There are fewer annual operations associated with perennial energy crops and so some farmers may opt for a slightly lower income in return for a less arduous crop management regime.

Farmers and suppliers identified climate change mitigation and reducing fossil fuel dependency as imperative over the longer term (see again Fig. 3). This is perhaps due to their reliance on fuel for machinery, which affects several farming operations. These drivers were also recognised by Sherrington et al. [40] as a potential motivation to grow energy crops.

The fourth most important driver was the potential attractiveness of the growing bioenergy market. Given that the most important driver was to make a profit, with climate change and fossil fuel depletion also considered important, it follows that farmers and suppliers may be driven by entrepreneurial motives towards renewable energy, in order to secure a more diversified market.

6.3. Developer/owner stakeholders of bioenergy projects

6.3.1. Barriers to developing bioenergy projects

Technology is identified as the most critical barrier (see Fig. 4), as many developers found that some biomass technologies were unproven, commercially unviable, or there was a lack of UK knowledge and experience. This is perhaps a reflection of the fact that the UK's bioenergy industry is still in relative infancy. As previously discussed (see Section 3), there have also been a number of failed or slow developing bioenergy projects in the UK. However, when compared to some other EU countries, it is apparent that for many bioenergy production pathways, technology is not always the most important barrier. McCormick and Kaberger [10] found that learning processes and optimising systems were important. They argued that there were no technical issues that represent overriding barriers to bioenergy development.

Development and operational cost were identified as the second most significant barrier, which is understandable when introducing new technologies. It is likely that, as the bioenergy industry expands in the UK, 'economies of scale' can be achieved and costs will reduce. However, the logistics of biomass systems require feedstocks to be inexpensive to produce and transport in comparison to fossil fuels. Associated with this, depending on their energy content and density, they are often required to be located close to the conversion point to minimise transport costs. High capital costs are associated with most bioenergy technologies, and

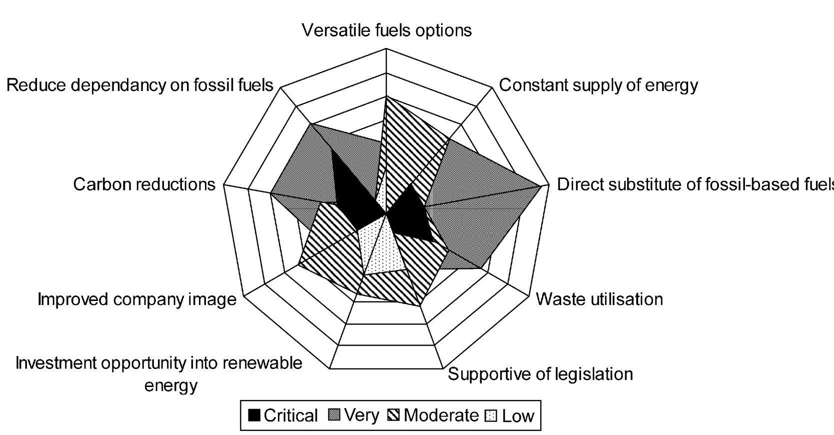


Fig. 7. Drivers to bioenergy development according to primary end-users of bioenergy.

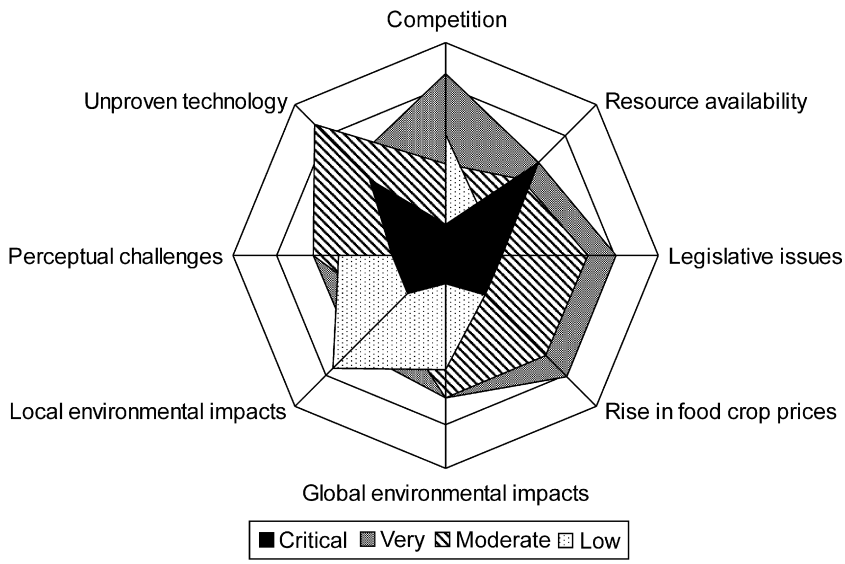


Fig. 8. Barriers to bioenergy development according to government/policy stakeholders.

respondents to the survey also identified uncertainty over, or lack of, grant funding as an important 'other' barrier, which is closely linked to costs of production.

For biomass electricity production, both technology and cost barriers could be reduced in the UK with the introduction of banding under the Renewables Obligation (RO). Since 1st April 2009, emerging technologies, such as anaerobic digestion, gasification and pyrolysis, now receive two Renewable Obligation Certificates (ROCs) per MW h of electricity produced, which is twice the support previously received [45]. The main objectives of the RO are to incentivise renewable electricity in the UK, and to provide longer term confidence for investors. Banding of the RO has provided more support for technologies that are currently further off from commercial deployment.

Legislative issues are an important barrier for developers as they need to be familiar with a variety of regulations, depending on the technology they adopt. For example, they may need to be familiar with Integrated Pollution Prevention and Control (IPPC), Renewables Obligation, Renewable Transport Fuels Obligation (RTFO), and local planning requirements. If using waste as a feedstock, developers also need to be aware of the Waste Framework Directive and the Waste Incineration Directive [46]. Compliance with this range of legislation can be complex and costly.

Resource availability was identified by respondents as the fourth most important barrier for developers. Clearly markets for biomass face competition from other industries, such as food, chemicals, polymers and fibres. In particular, energy crops face direct competition for land from food and feed crops [47]. The Royal Commission on Environmental Pollution (RCEP) and the Biomass Task Force in the UK identified the fuel supply chain as a key barrier to bioenergy development [35,48]. Developers increasingly need to devise flexible approaches to feedstock supply in response to changing market conditions.

6.3.2. Drivers for developing bioenergy projects

Financial reward and support are the primary drivers for bioenergy developers (see Fig. 5) in a similar manner to farmers/suppliers. Market opportunity is an important driver for developers as they can see the business case for entering an expanding bioenergy market; without this it is unlikely that developers would invest in bioenergy schemes. The desirability of climate change mitigation and reducing dependency on fossil fuels were the third

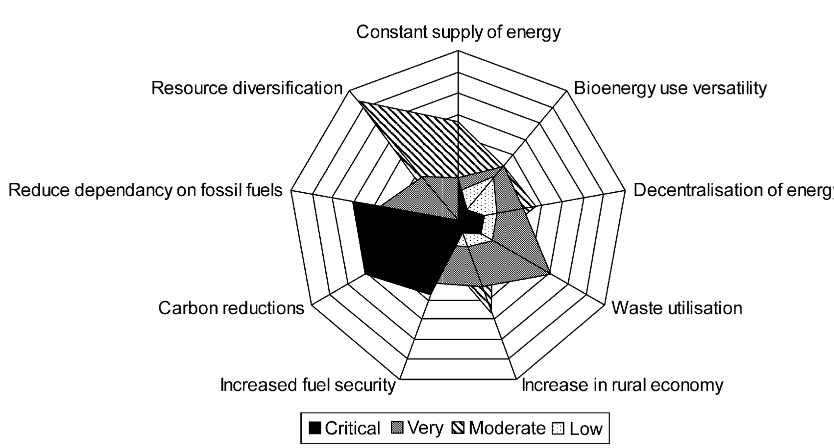


Fig. 9. Drivers to bioenergy development according to government/policy stakeholders.

and fourth most important drivers respectively. This was again similar to the views expressed by farmers/suppliers.

6.4. Primary end-user stakeholders of bioenergy

6.4.1. Barriers to an increase in the end-use of bioenergy

Consumers and businesses often make buying decisions primarily based on cost. This is demonstrated in the survey with nearly all respondents (88%) stating that the high purchase costs of bioenergy, in comparison to fossil fuels, was a 'critical' or 'very important' barrier (see Fig. 6). Compared to the other barriers identified, this was the most significant, and highlights the importance of end-user economic decision-making. The development of bioenergy is therefore highly dependent on its cost competitiveness against fossil-based fuels. Generally, examples of successful bioenergy projects have competed with other sources of energy on price. For example, some biodiesel production schemes for road transport are able to compete financially with fossil-based diesel [49]. Obviously the issue of fuel poverty is related to the cost of bioenergy, as highlighted in the Energy White Paper [16]. There the UK Government highlighted the need to address the negative consequences of rising energy prices on low income consumers. Successful future development of different bioenergy pathways and individual projects will therefore depend, for all these reasons, on the ability to compete long term with fossil-fuel prices.

Legislative issues, such as government policy or international standards, were also identified by end-users as important. This is perhaps a reflection of the multiplicity of legislative interventions, which affect different aspects of bioenergy. New infrastructure requirements were also viewed as an important barrier. These include: new biomass heat installations, storage requirements for co-firing, or cars requiring engine alterations to accept higher levels of biofuel blending [36]. This new infrastructure will require capital investment and may not always be practical or economic. Uncertainties surrounding adaptability are also important, for example the limits for co-firing or blending of biofuels.

Several end-users (as with developers and suppliers) identified insufficient available supply as their fourth most important barrier. This finding is repeated across each stakeholder group, and is closely linked (or cross-related) with the economics of bioenergy production. Where supply fluctuates over time, so does the cost of bioenergy. End-users will usually require a constant supply of energy resource, which is available on demand. Where bioenergy cannot offer this, it is unlikely that the end-user will switch away from their existing sources of energy. The challenge of public perception perhaps reflects the significant media interest in bioenergy over recent years. Much has been written about first generation biofuels and the competition for land with food crops (e.g. [42,43,47]). Bioenergy has also been criticised as a potential cause of deforestation, and for disturbing carbon sinks, such as peatlands and tropical forests [50]. Whilst this could be true in some cases, this is often not the case and the mixed media messages contribute to a public perception barrier. The public are also often opposed to having bioenergy projects near to where they live. For example, the phrase 'Not In My Back Yard' (NIMBY) is often associated with biomass energy projects [28,51].

Other barriers identified by respondents include a lack of vehicle manufacturer support, e.g. warranties being voided on biodiesel blends greater than 5%; difficulties securing long-term contracts for feedstock; security of new technology demonstration projects; and insufficient knowledge or experience of bioenergy.

6.4.2. Drivers for an increase in the end-use of bioenergy

Reducing dependency on fossil fuels, directly replacing particular fuels with bioenergy resources, and reducing carbon emissions are the most important drivers in this category of stakeholders (see Fig. 7). End-users noted the implications of varying oil, electricity and gas prices, and there seemed to be an increased awareness of climate change, energy security and fossil fuel depletion issues. Such end-users are therefore increasingly driven by a need to find alternative sources of energy, which are both renewable and produce reduced levels of carbon and other greenhouse gas emissions. Good examples of this include biodiesel for cars and woodfuel for household heat.

6.5. Government/policy stakeholders for bioenergy development

6.5.1. Barriers to supporting the use and development of bioenergy

In comparison with the other stakeholder groups, the barriers for Government and other policy-makers are much more evenly distributed (see Fig. 8). Resource availability is considered the most significant barrier, since there is limited unused, but productive land available in the UK. Therefore concerns arise over competition with food crops and reliance on imports to meet targets. This in turn means that the sustainability of the biomass resource is open to question. Rises in food crop prices were identified as an important barrier, and this is subject to an ongoing debate. It has become apparent that the increased demand of feedstocks for bioenergy has some impact on food prices [43]. However, there are other factors that affect prices including poor harvests, increasing population, and changing diets. Nevertheless, public perception is important over these issues in framing reactions to bioenergy developments, both in the UK and elsewhere.

To make a significant contribution to the UK energy supply, this group considered advanced conversion technologies to be essential. In the case of liquid biofuels, the Gallagher review [47] found that second generation technologies to be immature, currently expensive, and required specific incentives for their development. This is similar for other bioenergy pathways. Significant development of biomass supply chains is also necessary in order to increase the supply of bioenergy in the UK. Competition from other renewable sources of energy is very important, as governments must make decisions on where to direct their limited financial resources to help meet the renewable energy targets.

Several 'other' barriers were identified by respondents. The most important of these is the lack of skilled or trained workers in the bioenergy field. In comparison to more developed bioenergy industries, such as those in Germany, Austria or Finland, the UK lacks sufficient specialists, such as installers, operators, and maintenance engineers. Therefore, a large increase in skilled bioenergy workers will be required if the UK is to meet its renewable energy targets via a significant utilisation of bioenergy resources. This is also highlighted in other reports, such as that by the Biomass Task Force [35] and more recently in the UK Renewable Energy Strategy, which expects up to half a million jobs in the British renewables sector by 2020 [4].

6.5.2. Drivers for supporting the use and development of bioenergy

Reducing dependency on fossil fuels and reducing carbon emissions are the two most important drivers for Government and policy-makers (see Fig. 9). Increased fuel security and much better utilisation of waste are also considered as very important. These drivers coincide with those outlined in the recent Government strategies, such as the Energy White Paper [16], the Waste Strategy for England [44], and the UK Biomass Strategy [5]. The increasing price of oil and other non-renewable fuels was identified by several respondents as an important 'other' driver for increasing the use of bioenergy. Another driver is the relative cost of disposing of waste, which includes landfill tax and gate fees. Both of these drivers are obviously economically driven.

7. Limitations in the adopted methodology

With any questionnaire, there will always be the potential for bias and uncertainty [38]. Potential weaknesses in the online survey include the description of each barrier or driver, the way which the questions are worded, the order in which they are numbered, the stakeholder's background or point of view, or the sample size. An attempt was made to address these issues during the design of the questionnaire. For example, the survey allowed each barrier and driver to be rated in importance; a clear description was given for each barrier or driver; additional barriers and drivers could be added by respondents; and the questionnaire was only sent to individuals who were known to have key experience in the bioenergy industry. However, individual interpretations were clearly beyond the authors' control.

8. Concluding remarks

A range of barriers and drivers to UK bioenergy development have been identified through a comprehensive literature and case study review. These were then assessed through an online questionnaire completed by various stakeholders grouped: farmers/suppliers, developers, primary end-users, and government/policy. The survey questionnaire results show that although the barriers and drivers are different for each stakeholder group there are also some similarities between the groups. Whilst the diversity of bioenergy systems means that care needs to be taken when interpreting these findings, they do give a useful insight into the most important barriers and drivers to the development of bioenergy schemes.

Several links have been identified between the barriers of different stakeholder groups, and economic ones are common across the whole supply chain. The three most critical barriers for the suppliers of biomass feedstocks all relate to economic considerations. Developers identify development and operational costs, and uncertainty over government support schemes as very important. In the case of end-users, the biggest barrier is the high buying costs with respect to fossil fuels. Technology barriers are also common across some stakeholder groups. Developers and government/policy advisors rate the unproven nature of conversion technologies as a critical barrier.

Barriers for developers appear very technology based. The uncertainty and hesitance of bioenergy developers suggests that conversion technologies are often not reliable or profitable. This may change with the development of UK Government incentives: the double ROCs, the clean energy cash back, and the renewable heat incentive. However, developers also cite feedstock availability as a barrier and so again, mechanisms to link farmers and developers would be beneficial. End-users will predominantly buy the cheapest and most reliable fuel. Therefore, financial support mechanisms are required to make bioenergy more competitive.

Reducing carbon emissions and dependency on fossil fuels is the main common thread between the drivers for all stakeholder groups. Clearly net energy and carbon balances for bioenergy projects must be proven in order to meet these concerns. This is also of critical importance when the sustainability of bioenergy schemes is considered. However, suppliers and developers both rate economic drivers as being of critical importance. This is understandable as both groups are commercial 'actors' that rely on profit for survival.

The present research highlights a number of implications for the future of bioenergy in the UK. In order for bioenergy to be successful the growth of energy crops must be profitable for the farmer in both the short and the long term. Competition with food for land is problematic both in terms of food production, but also in terms of public perception of the use of bioenergy. Therefore, mechanisms to promote alternative biomass feedstocks, such as farm wastes, ought to be considered. However, the sustainability of bioenergy is key, and care must be taken to ensure that any bioenergy technologies promoted and supported do lead to a reduction in greenhouse gas emissions.

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